ELEC5306 Video Intelligence and Compression
Project #1: JPEG Compression

Due: 02 April 2023 11:59PM

1 Objectives

- 2D discrete cosine transform
- Explanation for run-length coding
- Explanation for quantization table
- Evaluation in PSNR

2 Questions

2.1 2D discrete cosine transform

- Write a function, dct_2d_type_2_norm_ortho(img), to perform 2D discrete cosine transform. The function should be exactly the same as

```
scipy.fftpack.dct(x, type=2, n=None, axis=-1, norm='ortho', overwrite_x=False).
```

Hint:

The equation for this transform is at `https://docs.scipy.org/doc/scipy/reference/generated/scipy.fftpack.dct.html`. More specifically, Type II, with $norm =' ortho'$.

2.2 Explanation for run-length coding

The function run_length_coding takes a 1D array as input, output symbols and values. Symbol is a list of pairs in the format of (A, B). Value is a list of $char$.

- Explain the meaning of A, B, and $char$.
- Given a pair of 'symbols' and 'values', get the original array from it.

Hint:

Besides reading the code, a more straightforward way is to input an actual array to the function run_length_coding and print the output. This is also useful to double check the recovered original array.

2.3 Quantization table

- Explain the effect of the scalar of values in the quantization table.
- Explain why values in the top-left corner are lower, and those in the right-bottom corner are higher.
- Design a quantization table that causes no loss in information in this quantization step given the coefficients from DCT are all integers.

Hint:
The spatial location of the element is related with the frequency in cosine-transformed map.

2.4 PSNR

- Write a function, `psnr(image1, image2)`, to calculate PSNR for a pair of images.
- Calculate the PSNR for the original image and the compressed image.

Hint:
Use Numpy for tensor calculation. The formulation of PSNR is given in `https://en.wikipedia.org/wiki/Peak_signal-to-noise_ratio`.

2.5 Analysis

- define two new quantization tables
- compress the original image with those tables respectively
- calculate the PSNR of those images against the original one respectively
- text analysis about how the quantization table affect the quality (the PSNR) of the generate image

2.6 Gray-scale

- Convert the color image to a gray-scale one
- perform the compression for this gray-scale image (encode, decode, visualize)

3 Submission and Grades

You are supposed to finish this project by yourself. Your submission, a jupyter notebook, should include

- the complete code that was well-commented.
- results including numbers, analysis text, and figures.

The file should be named as '**project1_unikey.ipynb**' with no spaces in the file name and submitted on *Canvas*, e.g. '**project1_abcd0123.ipynb**'. Note that your codes need to be well commented and the written part needs to have clear sections. It is important that the results must be generated by the source codes you submitted, otherwise your work may be regarded as plagiarism. More detailed requirements are as follows:

- Your submissions should strictly follow the instructions.
- Your codes are correct, well organized and well commented.
- The written part are well organized and has few typos. The report should contain the correct formulas when they are necessary.
- The visualization results are clear and well defined.
- You have shown your insights into the results and drawn some reasonable conclusions.
- No copy from your classmates. If you and some of your classmates copied codes from the same online resource, you will also be penalized if you do not make any modifications or provide the reference.
- Give references on all the codes and papers you referred to.

Appendix: Marking Scheme

The total marks for Project 1 is 20 in your final score, and Question 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 accounts for 20%, 15%, 15%, 25%, 10% and 5% respectively, the format and submission accounts for 10%. The numbers in the following chart are in percentages.

Q2.1	the code runs successfully and gets the same result of the built-in function	15
	the code is well-annotated	5
Q2.2	correct explanation	5
	correct array	10
Q2.3	reasonable explanation of the scalar	5
	reasonable explanation of the pattern	5
	right quantization table	5
Q2.4	correct PSNR function	15
	get the PSNR of two images required	5
	well commented codes	5
Q2.5	reasonable quantization tables	2
	do compression and decoding	5
	calculate the PSNR	2
	detailed analysis	5
Q2.6	well-commented	1
	the code w/o error	4
punishment	cheating	-100
	late submission per day	-5
	messy file	-20